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EXTENSION OF TORONTO TEMPERATURE TIME-SERIES

by

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ATMOSPHERIC ENVIRONMENT SERVICE

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ABSTRACT

Daily maximum and minimum temperatures for Toronto City exist and are archived from Mar. 1, 1840 to the present day. This lengthy time series can be extended considerably by using standard differences in mean monthly temperatures between Toronto and a number of United States stations, the earliest of which dates from July 1778. In addition, there are considerable temperature data taken three times a day from another station in Toronto in the 1830s decade. These data were adjusted and monthly mean temperatures calculated.

SOMMAIRE

Les températures maximales et minimales quotidiennes de la ville de Toronto existent dans les archives du 1er mars 1840 à aujourd'hui. On peut étendre de beaucoup cette longue série temporelle, en utilisant les écarts-types de températures mensuelles moyennes entre la station de Toronto et plusieurs stations des Etats-Unis, la date la plus ancienne tombant en juillet 1778. En outre, de 1830 à 1840, on a établi un nombre considérable de données sur la température, relevée trois fois par jour, à une autre station de Toronto. On a rajusté ces données et calculé les températures moyennes mensuelles.

EXTENSION OF TORONTO TEMPERATURE TIME-SERIES FROM 1840 TO 1778 USING VARIOUS UNITED STATES AND OTHER DATA

PURPOSE

In December 1839, the British Government established a meteorological and magnetic observatory at Toronto, Ontario. Some sporadic observations began late in the month at Fort York, on the shore of Lake Ontario just west of the town, then called York. Fixed hourly observations of temperature commenced in the new year, but it was not until March 1, 1840 that regular daily maximum and minimum values were recorded, and on this date daily digital archive readings begin. On September 5, 1840, the observation site was moved to the University of King's College, now the University of Toronto, about two kilometres north of the lakefront. Although a number of small changes in location occurred in later years, a relatively homogenous, high-quality data set extends from September 1840 to the present day. However, the rather large urban heat-island effect, which influences the records of all such large cities, is evident.

The Toronto record from 1840 to the present comprises the longest continuous temperature time-series in the Canadian climatological Archive, and thus it is frequently used in the analyses of long-term temperature trends.

The purpose of this paper is to present a method of extrapolating the Toronto temperature time-series backwards from 1840, using various United States and other data. The earliest American data used in the analysis were taken in 1778.

SOURCES OF EARLY CLIMATIC DATA USED FOR COMPARATIVE PURPOSES

Toronto Area

The first fragmentary climatic data for Toronto were taken in the year 1801. These are contained in the Hodgins Papers in the Archives of Ontario, Toronto, and date from the late nineteenth century. The data are identical to that published in the Upper Canada Gazette at the time the observations were taken, so it may be presumed that Dr. Hodgins merely copied long-hand this original source. The data include the temperature and weather or sky condition at three fixed times a day. Similar data were published for a number of months in the same newspaper around 1820. Neither data set was lengthy enough to be used in this study.

Later a longer, more useful data set was taken by Charles Dade (1831-1841) from January 1831 to April 1841. Rev. Dade was the Head-

master of Upper Canada College, then situated close to the centre of the town on the lake shore, not far from the later Fort York station. The thermometer was read two or three times a day at fixed times, but slight changes in the reporting hours occurred during the decade and occasionally only one observation was taken in a day. Only a few months were incomplete, except for an extended period from October 1838 to June 1839 when Rev. Dade returned to England for the winter.

In Figure 1 are shown the periods of record for the various early Toronto stations used for the purposes of comparison. Data from Fort York is combined in the Archive with the University station and identified as "Toronto" (no modifier), but is unofficially called "Toronto City." Data later than 1855 were not considered.

Remainder of Southern Ontario

Data for Ancaster, about 65 km southwest of Toronto, were taken by Craigie(1835) from January 1835 to December 1845 and proved to be only of limited use in the Toronto data extension. William Craigie was a surgeon who apparently tabulated daily maximum and minimum temperatures as well as fixed-hour readings. His thermometers "were in a northern exposure, five feet from the ground, and shaded from the effects of direct insolation and radiation from the sky." However, only newspaper tabulations of monthly means of the 9 a.m. and 9 p.m. observations survive.

American Stations

Mean monthly temperature data were abstracted from the Smithsonian Institute(1927) for Albany, New Haven and New York City and the United States Weather Bureau(1932-1937) for Albany, Baltimore and Rochester. Considerable monthly data were also available from grammar schools in New York State. These were published by Hough(1855,1872). Data for Auburn, Buffalo, Cortland, Fairfield, Fredonia, Hamilton, Lewiston, Lowville, Oneida, Rochester(College) and Utica were used, other stations listed in the above publications having insufficient useful data.

All stations actually used in the study are shown in Figure 2. In the case of the New York State grammar school records, there were many missing months and years for most stations, and only the first and last years of data are shown. In all cases, data later than 1855 were not used.

In the case of most of these early data, excepting Toronto(city), observations were taken with the thermometer attached to the north wall of a building. Recording maximum and minimum thermometers were not generally used. Monthly means were computed from two, three or more observations a day, and the time and number of daily observations frequently changed and were not consistent, either at a site or from one station to another. In addition, the thermometers may not have been calibrated accurately or sufficiently shielded from insolation, and changes in exposure or siting may not have been recorded.

METHOD OF ESTIMATION OF TORONTO MEAN TEMPERATURES

Three distinct methods were employed in the calculation of Toronto mean temperatures due to significant differences in the form of the source data: monthly means at the American stations(calculated by a variety of methods depending on the station); daily data for Dade; and monthly means for 9 a.m. and 9 p.m. in the case of Ancaster. As shown in Figure 3, these were labelled Method "S", Method "D", and Method "A", respectively.

All three methods were employed whenever data permitted. In deriving the final Toronto estimates, however, Method "D" was chosen whenever Dade data were available. Thus, Method "S" was used up to December 1830, but Method "D" from January 1831 to February 1840. For missing Dade months, Method "S" was substituted before 1835, but from this year on, a linear regression equation was used based on the 52 months when the calculated American data could be compared with both Dade and Ancaster calculations:

$$T = -0.126 + 0.6045\ T_A + 0.4108\ T_S,$$

where T is the estimated Toronto monthly mean (deg. F),
T_A is the estimated Toronto mean using Method "A",
and T_S is the estimated Toronto mean using Method "S".

Method "S"

This method essentially involved calculating standard differences between various American stations and Toronto. For example, since August is normally 4.5°F cooler at Toronto than at Albany NY, it was assumed that all missing August means at Toronto for which data were available at Albany could be reasonably estimated by subtracting 4.5° from the Albany values, no matter whether the month was near normal or significantly below or above normal.

Method "S" is outlined in Figure 4. There are five distinct steps:

1. Difference calculations. Mean monthly temperature data for Toronto(city), 1840(March-December)-1870, and for all available American stations within about 400 miles of Toronto having significant data before 1870 were tabulated. Sixteen distinct U.S. stations were available. Most stations did not have data before 1820, but New Haven CT had data as early as 1778(Figure 2). In order to facilitate comparison of data from all stations, for each individual month, differences were calculated for all possible stations pairs, for example, Toronto minus Rochester, Toronto minus Albany, Toronto minus New Haven, ... Rochester minus Albany, etc.

2. Correction and deletion of bad data. The differences for each station pair were tabulated by month and year and the overall monthly mean differences calculated. Also, standard deviations of the mean mon-

thly temperatures for each station were calculated. Then, for each station pair for each of the twelve months, an average standard deviation was calculated, and all differences greater or less than one standard deviation were identified. For example, the s.d. of the August means at Toronto is 1.8°, Albany 2.2°, for an average of 2.0°. The mean difference for the month, Toronto-Albany, is -4.5°, so that the 1 s.d. range is -2.5° to -6.5°. By idendifying differences outside the 1 s.d. range, it was easy to spot unusual months or questionable data. For any month for which no station pair differences lay outside the 1 s.d. range, the data were assumed to be reasonably good. Otherwise, a subjective assessment was made by the areal plotting of the means and departures from normal. In a few cases, it was possible to correct a value when it was obvious that a typographical error of 10°F had been made in the printed source. Most questionable data, however, were discarded.

3. Choosing of stations and periods for analysis purposes. Following the corrections and the discarding of questionable months, a new data set for each of the 16 American stations was prepared. The Toronto data was assumed to be "good" and the aim was to choose as many of the 16 U.S. stations as possible for the 1840-1870 period for the purposes of comparison. Many of the stations had missing or discarded data in the last half of this period, so it was necessary to use only the 1840-1855 period. Within this period, not enough data were available for the computation of reasonable monthly means at Auburn or Buffalo, and the data for Rochester College were identical to or varied by only a small constant from the Rochester data and hence were suspect. The number of U.S. stations for the purposes of comparative analysis was therefore reduced to 13.

4. Standard difference calculations. For each of the 12 months, mean differences in monthly temperatures between Toronto and each of the 13 American stations were calculated. The calculations were based on all months, September 1840 to December 1855, inclusive. It was felt that the early data for Toronto, March to August, 1840, taken near the lake shore at Fort York, were not homogeneous with the later University site observations. Because of some missing months for most U.S. stations, the standard differences were calculated from means based on 10 to 15 years in most cases, and which varied from month to month and from station to station. The standard differences between Baltimore and Toronto ranged between 10.0° and 13.5° depending upon the month. Because of its great distance from Toronto and the resulting high and variable differences in the monthly mean temperatures, it was decided to eliminate Baltimore. Thus, only 12 stations were left for further analysis.

5. Calculation of Toronto means. For each month, July 1778 to February 1840, an estimated mean temperature for Toronto was calculated separately based on each American station for which a mean monthly temperature was available. Thus, in June 1831, the mean monthly temperature at Albany was 72.8°F, and since the standard difference, Toronto-

Albany(based on 1840-1855)is -6.8°, the Toronto mean was estimated 66.0°. Similarly, New Haven was 71.1° in the same month, and the standard difference, Toronto-New Haven, is -5.5°, so that Toronto's mean was calculated as 65.6°. The overall Toronto mean was calculated as the unweighted average of all the individual estimates from the various U.S. stations, which for any month would vary from 1 to 12 stations. This method of estimating Toronto means was checked against the actual means from September 1840 to December 1855. Although some monthly errors were as great as 4.0°F, the standard deviations of the errors varied from 0.94 to 1.75 for individual months, averaging 1.17°.

METHOD "D"

In the case of Dade data, mean monthly temperatures had to be calculated from two or three hourly observations a day. Then, standard difference calculations were made by comparing Dade monthly means with those of several American stations. Toronto monthly means were also compared to the same U.S. stations for the period 1840-1855. In this way, a first approximation was made of Toronto-Dade differences. The period of the Dade observations was somewhat cooler on average than that of the later Toronto observations. Consequently, a second approximation of the Toronto-Dade differences was made, allowing for mean temperature differences between the two periods. When Toronto means were calculated month by month using these second approximation differences, a comparison with the means obtained by using Method "S" showed a consistant low bias. Hence, a final approximation of Toronto-Dade differences, and therefore, calculation of Toronto means, was made to allow for this low bias.

Method "D" is outlined in Figures 5 and 6. There are eleven distinct steps.

1. Estimation of daily maximum and minimum temperatures. When Rev. Dade began observations on January 1, 1831, he took readings at 9 a.m., 3 p.m. and 6 p.m. However, this pattern did not continue in later months and years. Sometimes the morning reading was at 7 or 8 a.m., but the mid-day observation was usually taken at noon and the evening one at 5 p.m. To complicate matters, while there was always a morning reading(excepting the months with partial days, which were excluded from analysis), sometimes there was in addition only a mid-day reading, sometimes only an evening one, sometimes both, and sometimes neither. It was necessary, therefore, to estimate daily maximum and minimum readings. This was done by using mean hourly temperatures in comparison with mean daily maxima and minima for each month at Toronto's Pearson International Airport(Atmospheric Environment Service, 1978). Thus, a correction factor was calculated to be subracted from the morning reading to estimate the daily minimum and to be added to the mid-day and evening observations to estimate the daily maximum. These applied to Pearson Airport, so corrections for Dade were computed by multiplying the Pearson corrections by the ratio of the monthly mean daily range at Toronto(City)to that at Pearson. These figures were rounded to the nearest whole Fahrenheit degree. According to modern practices, the

"climatological day" for a climatological station that takes only observations in the morning and evening ends with the evening observation as far as the daily minimum is concerned and with the morning observation as far as the daily maximum for the previous day is concerned. The daily minimum for Dade observations was calculated as the lowest of (a) the actual evening reading the day before, (b) the morning observation corrected for the diurnal minimum, (c) the mid-day actual reading, and (d) the evening actual reading. Similarly, the daily maximum for Dade was calculated as the highest of (a) the morning actual reading, (b) the mid-day observation corrected for the diurnal maximum, (c) the evening observation corrected for the diurnal maximum, and (d) the morning actual reading the following day. In those rare cases where neither mid-day nor evening observations were taken, the minimum temperature for the day was calculated as above. Then a maximum was estimated using the mean daily range for the month at Toronto(City). This value was checked against the morning temperature the following day and the higher of the two taken. Hence, the daily maximum and minimum calculations took under consideration abnormal diurnal temperature trends.

2. Calculation of mean monthly temperatures. For each month, the mean daily maximum and mean daily minimum were calculated from the daily values. The mean monthly temperature was then simply the mean of the mean daily maximum and the mean daily minimum.

3. Standard difference calculations, Dade minus U.S. stations. In order to estimate Toronto mean temperatures by using Dade data, it was necessary to compare Dade monthly means as computed above to those of as many American stations as possible. For each of the 12 months for the period January 1831 to April 1841, mean differences in monthly temperature were calculated between Dade and each of 9 U.S. stations: Albany, Cortland, Fredonia, Lewiston, New Haven, New York, Oneida, Rochester, and Utica. Data for Fairfield, Hamilton and Lowville were not used in this analysis due to many missing months during the decade.

4. Standard difference calculations, Toronto minus U.S. stations. Similarly, for each of the 12 months for the period March 1840 to December 1855, mean differences in monthly temperatures were calculated between Toronto and each of the 9 U.S. stations used in the Dade standard differences above.

5. First approximation of Toronto-Dade differences. Since both Toronto and Dade means are compared to the same 9 American stations, the first approximation of Toronto-Dade differences was obtained by subtracting the Toronto standard differences above from the Dade standard differences above. These were calculated separately for each of the 9 U.S. stations and the overall mean taken for each month. This analysis indicated that for every month of the year Dade values were high, and that correction values ranging from -0.6°(February) to -4.0°(July) had to be applied to Dade means to give a reasonable estimate of Toronto means. For the bitterly cold December of 1831, as an example, the Dade calculated mean was 15.8°. Since the correction value for December is -2.2°, the first approximation of the Toronto mean for the month would be 13.6°F.

6. Comparison of mean temperatures, period 1831-1841 with period 1840-1855. There was no reason to assume that the whole period 1831 to 1855 was climatologically homogeneous. In order to obtain a measure of the differences in mean temperature between the early period of the Dade observations(1831-1841) and the later period of the Toronto observations (1840-1855), calculations were performed for the three U.S. stations with the best and most continuous observations, Albany, New Haven and New York. Means were calculated for each month separately for each of the three stations and for both periods, allowing for those months during which Dade observations were missing. For each month, an overall mean difference(unweighted average of the three stations)between the period means was obtained. The earlier period was colder than the later at each of the three stations for each of the 12 months. The overall monthly differences ranged from 0.4°F for April to 2.5°F for December.

7. Second approximation of Toronto-Dade differences. The second approximation takes under consideration the fact that the earlier 1831-1841 period was significantly colder than the later 1840-1855 period. The first approximation Toronto-Dade differences were increased by the overall mean differences between the two decades. For example, for July, the first approximation Toronto-Dade difference in mean temperature is -4.0°. The difference between the two periods for the same month is 1.2°, so that the total correction applied to Dade means to obtain Toronto means is -5.2°F. Because of the variability from month to month, Fourier smoothing was applied to the monthly values. As a result, the second approximation of Toronto-Dade differences ranged from -2.7° in September and October to -4.1° in December. Again, in the case of the frigid December of 1831, the Dade mean of 15.8° with a correction of -4.1° results in a Toronto mean of 11.7°F. This is 1.9° lower than the first approximation calculation.

8. Preliminary calculation of mean Toronto temperatures using Dade and second approximation differences. For each month for which Dade means were available in the period January 1831 to April 1841, a Toronto mean was calculated using the second approximation differences(Fourier smoothed)above.

9. Comparison of mean temperatures at Toronto by using Dade calculations above and by using Method "S". For each month for which Dade means were available in the period January 1831 to April 1841, the Toronto mean using the Fourier smoothed second approximation differences with Dade were compared with means as calculated by Method "S", which uses all available American data. The overall mean differences in the two methods were compiled for each month and it was found that Method "S" gave higher values than the Dade method in the case of all months, ranging from 0.4° in March to 2.6° in February. The standard deviation of the monthly differences between the two methods ranged from 0.6° in June to 1.7° in January. In the case of the frigid December of 1831, Method "S" indicated a Toronto mean of 14.1°F, 2.4° higher than the preliminary calculation using Dade.

10. Final approximation of Toronto-Dade differences. Since Method "S" indicated somewhat higher means for Toronto for every month of the

year than those by using the preliminary Dade calculations, it would appear that the second approximation allowing for the mean temperature differences between the two periods was based on differences that were too great. Consequently, the final approximation of Toronto-Dade differences was calculated by reducing the second approximation differences by the differences indicated between Method "S" and the preliminary Dade calculations above. Thus, the December second approximation Toronto-Dade differences, Fourier smoothed, is -4.1°, the correction due to the Method "S" comparison is +1.7°, so the final Toronto-Dade correction for the month is -2.4°. Again, because of the month-to-month variation in the correction values, a Fourier smoothing was applied. The final approximation of Toronto-Dade differences then ranged from -1.1°F in October to -3.2°F in June. In the case of bitterly cold December 1831, the smoothed final Toronto-Dade difference is -1.9°, so that when applied to the Dade mean of 15.8°, the Toronto estimate works out to be 13.9°, very close to the 14.1°F in the case of Method "S".

11. Final calculation of Toronto means. For each month for which Dade means were available in the period January 1831 to February 1840, a Toronto mean was calculated using the final approximation differences (Fourier smoothed)above.

METHOD "A"

In the case of the Ancaster data, published monthly means based on two observations per day, 9 a.m. and 9 p.m., had to be corrected to standard monthly means based on daily maxima and minima. Then, standard difference calculations were made between the overlapping records of Ancaster and Toronto. From these, estimates were made of Toronto means for those months before records began in March 1840.

Method "A" is outlined in Figure 7. There are three distinct steps.

1. Correction of mean monthly temperatures. No daily observations are available for Ancaster, only published monthly means of 9 a.m. and 9 p.m. observations, from which a simple average was computed to produce a monthly mean. Correction values were calculated for each month in order to provide monthly means based on the modern practice of using daily maxima and minima. These were done by comparing means produced by averaging 9 a.m. and 9 p.m. monthly means at Toronto's Pearson International Airport(Atmospheric Environment Service, 1978)with the monthly means at the same station, which are calculated by the usual mean of daily maximum and minimum values.

2. Standard difference calculations. Ancaster and Toronto data overlap for the period March 1840 to December 1845. For each of the 12 months during this period, mean differences were calculated between the corrected Ancaster monthly means and the official Toronto means.

3. Calculation of Toronto means. For each month, January 1835 to February 1840, a mean temperature was calculated for Toronto using the corrected Ancaster mean and the standard differences above.

THE RECONSTRUCTED TORONTO TEMPERATURE TIME SERIES

By using Methods "S", "D", or "A" as appropriate, monthly mean temperatures were estimated for Toronto from July 1778 to February 1840. No American data were available for September 1778 or February, July, August, October, November and December 1779, so that no means could be estimated for these months. Beginning with January 1780, a complete set of monthly values was obtained. All calculations were done using the Fahrenheit scale, and then the whole set was converted to Celsius and combined with Atmospheric Environment Service Archive values that begin March 1840 and continue with no breaks until the present day.

Statistical F tests were applied to monthly and seasonal values to test the homogeneity of variance between various time periods. In the first instance, three 30-year time periods were chosen: (A) 1780-1809; (B) 1810-1839; and (C) 1840-1869. Period A involves only Method "S" and through much of this period only one, two or three American stations had data available for comparative purposes. Period B involves Dade data as well as an increasing number of U.S. stations. Period C involves the early instrumental record at Toronto before urban warming was significant. Only June temperature variances are significantly different at the 99% level between periods A and B and between A and C. In the second instance, two 40-year time periods were chosen: (A) 1801-1840 and (B) 1841-1880. Period A represents the last 40 years of reconstruction prior to the official observations beginning in March 1840, while Period B contains the first full 40 years of instrumental data. Only January variances are significantly different at the 99% level.

In Figure 8 are shown the individual plotted mean monthly July temperatures from 1780 to 1870. The cold July of 1816(the year without a summer)is immediately evident. The trend line is based upon a 50-year running mean.

In Figure 9 trend lines based upon 50-year running means plotted for the middle year are shown for all months. Fifty-year means over the period 1780 to 1987 can be plotted only from 1805 to 1962. Temperatures were considered constant before and after these dates. The overall rise in temperature during the period ranges from 0.9°C in January to 3.3°C in October, with an annual average of 2.2°C. A significant amount of this increase is no doubt due to the urban heat-island effect, which became increasingly significant from the 1880s on.

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FIGURE 1

EARLY TORONTO CLIMATOLOGICAL RECORDS

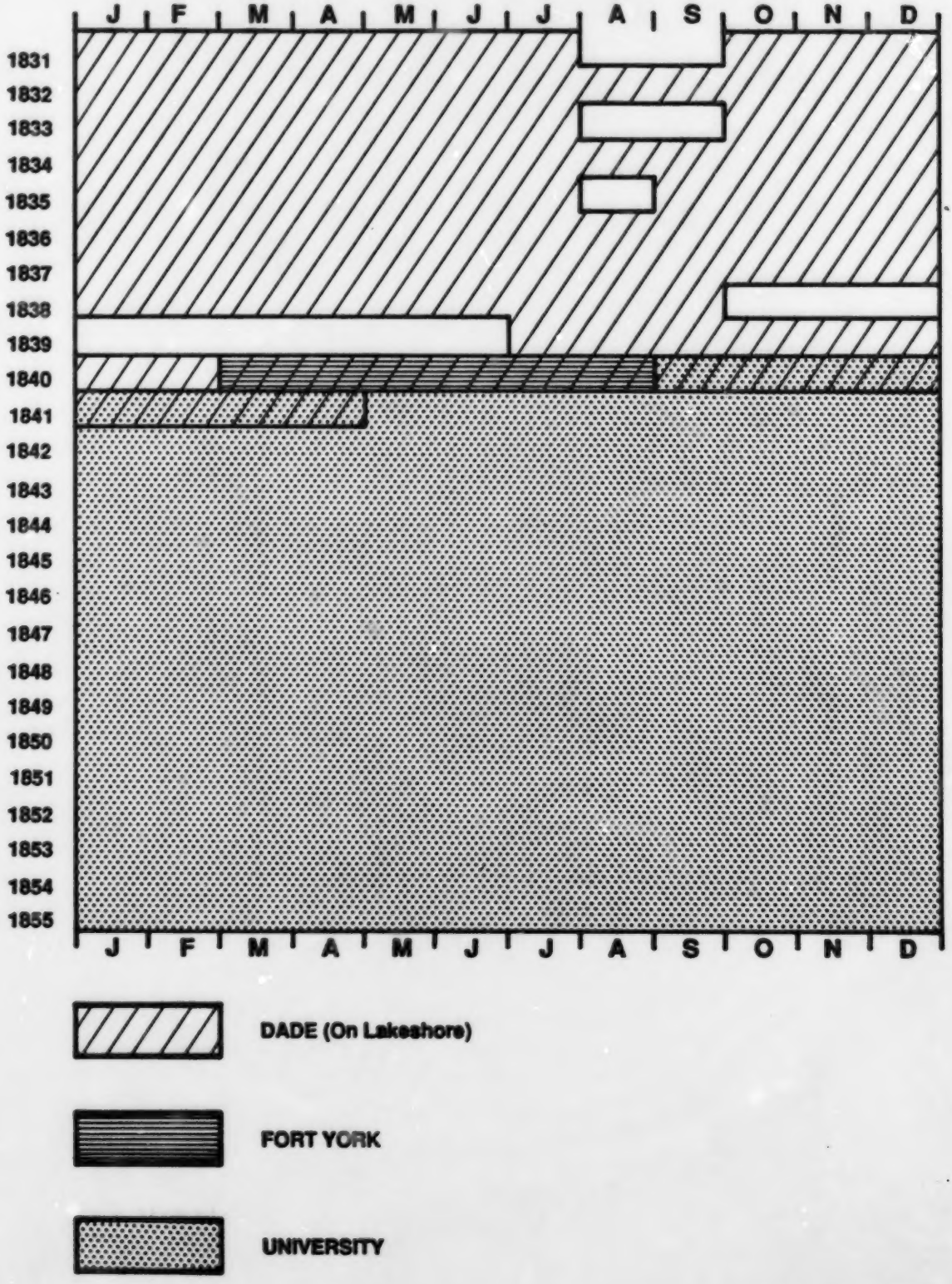


FIGURE 2

EARLY EASTERN NORTH AMERICA CLIMATIC DATA

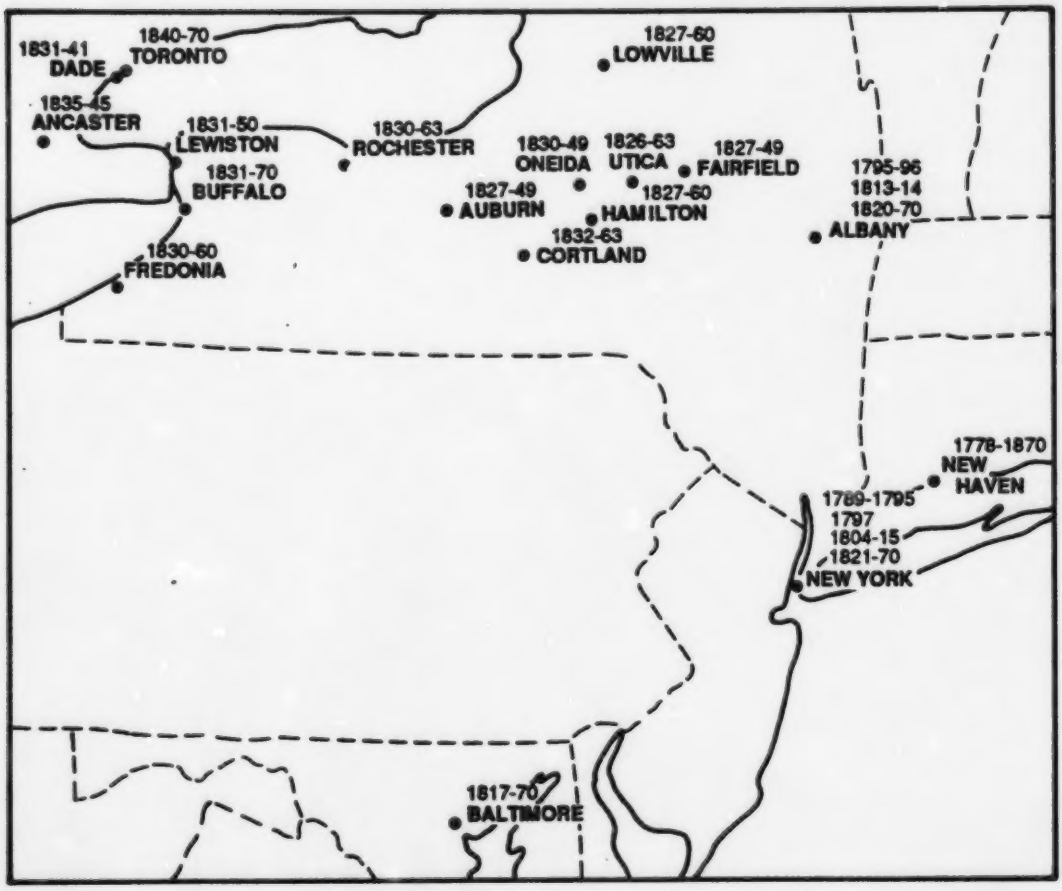
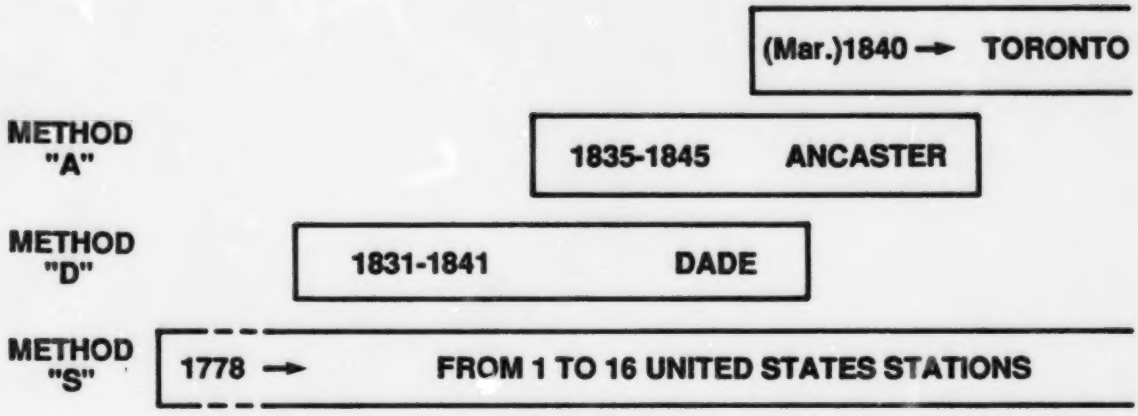


FIGURE 3

DATA USED TO ESTIMATE MEAN MONTHLY TEMPERATURES AT TORONTO



1. 1778-1830: METHOD "S"

2. 1831-1834: METHOD "D"
   (IF DADE MISSING: METHOD "S")

3. 1835- (Feb.)1840: METHOD "D"
   (IF DADE MISSING: REGRESSION EQUATION USING METHOD "S" AND METHOD "A")

FIGURE 4

METHOD "S"

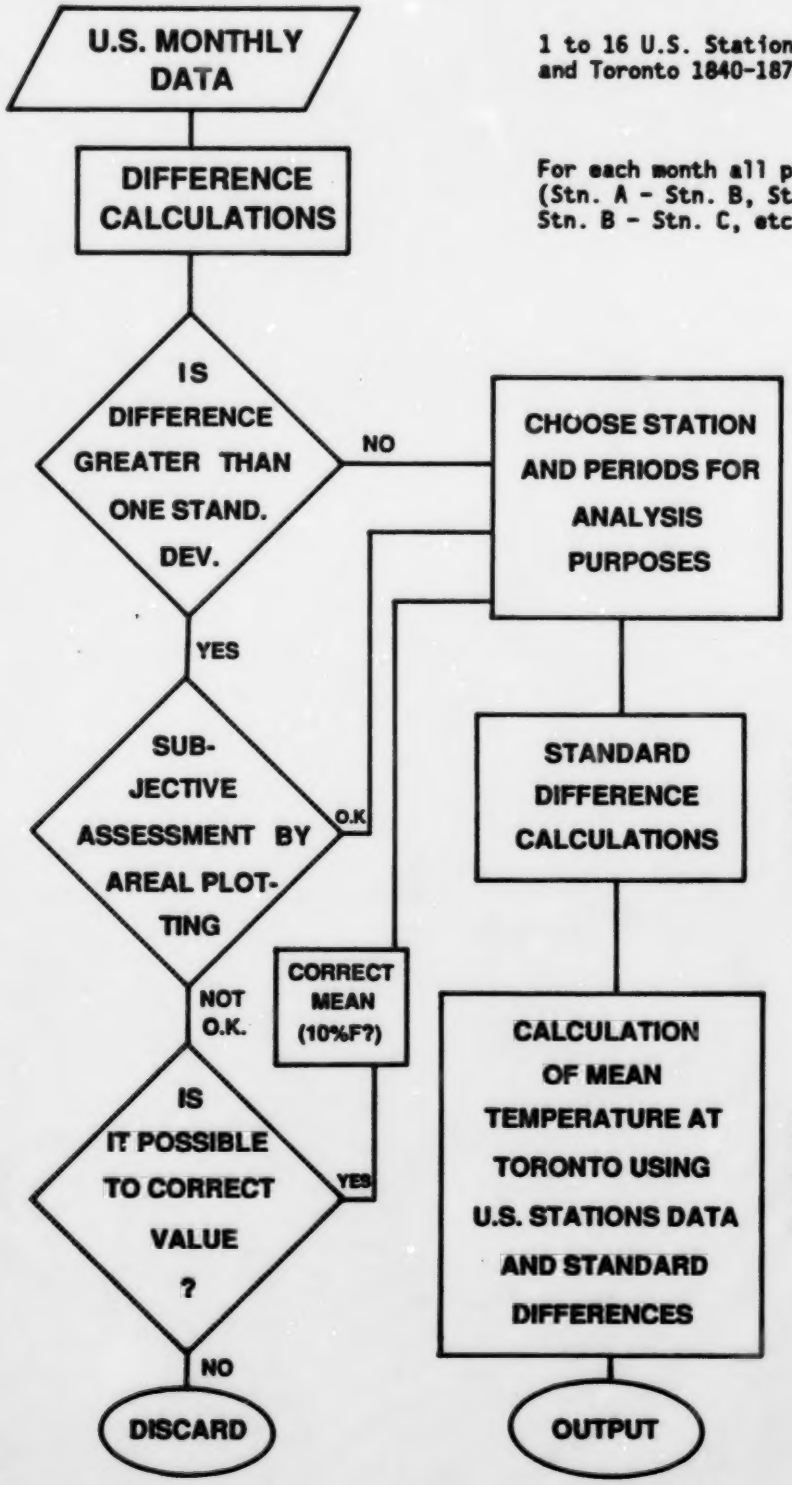

U.S. MONTHLY DATA
1 to 16 U.S. Stations 1778-1870 and Toronto 1840-1870
DIFFERENCE CALCULATIONS
For each month all possible station pairs (Stn. A - Stn. B, Stn. A - Stn. C, Stn. B - Stn. C, etc.
IS DIFFERENCE GREATER THAN ONE STAND. DEV.
NO
CHOOSE STATION AND PERIODS FOR ANALYSIS PURPOSES
YES
SUB-JECTIVE ASSESSMENT BY AREAL PLOT-TING
O.K.
STANDARD DIFFERENCE CALCULATIONS
For each of the 12 months Sep. 1840 - Dec. 1855 mean differences in monthly temperatures between Toronto and each of 12 U.S. stations
CORRECT MEAN (10%F?)
NOT O.K.
IS IT POSSIBLE TO CORRECT VALUE ?
YES
CALCULATION OF MEAN TEMPERATURE AT TORONTO USING U.S. STATIONS DATA AND STANDARD DIFFERENCES
For each month July 1778 - Feb. 1840 calculated separately for each station and unweighted average taken
NO
DISCARD
OUTPUT

FIGURE 5

METHOD "D"

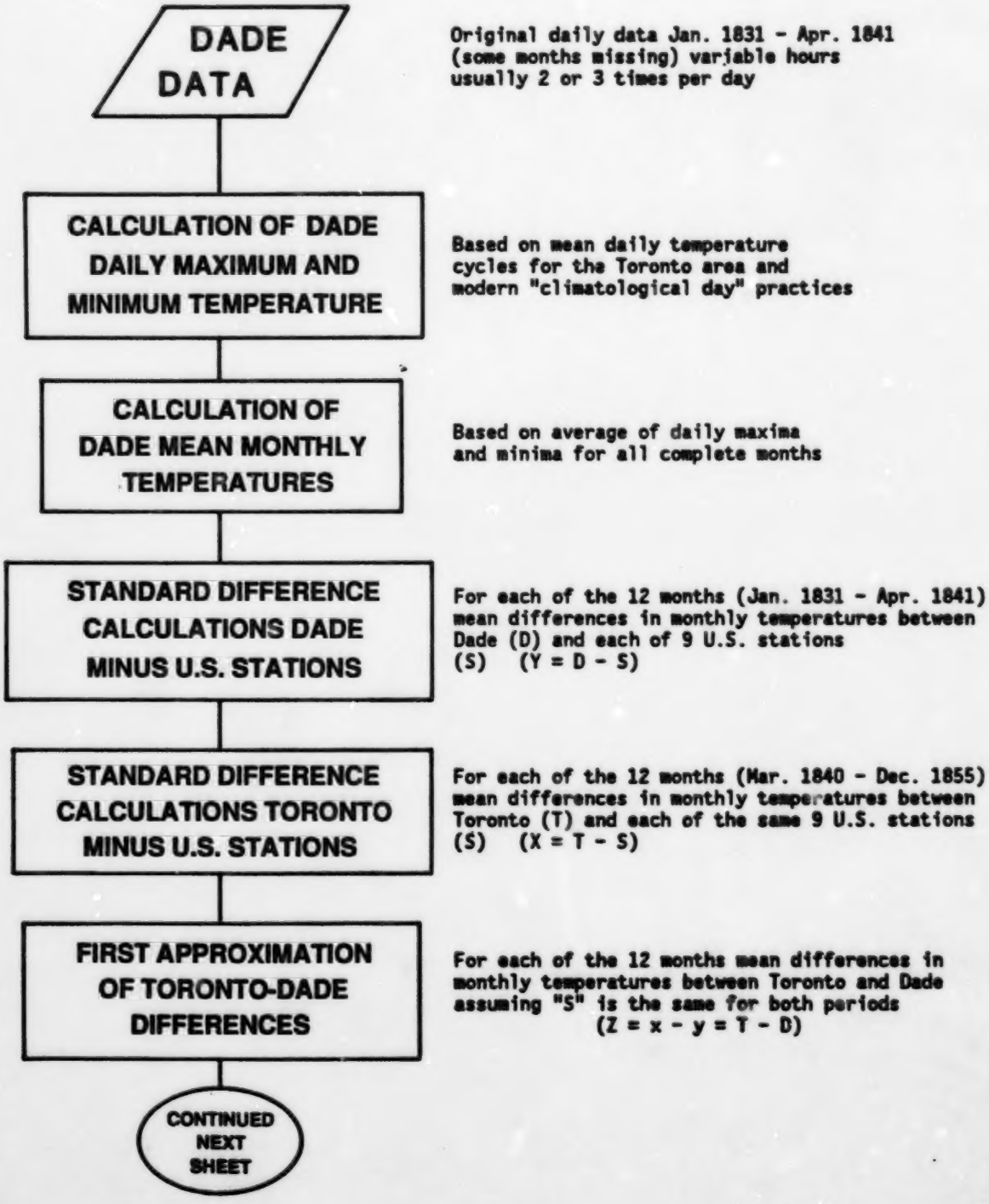

DADE DATA
Original daily data Jan. 1831 - Apr. 1841 (some months missing) variable hours usually 2 or 3 times per day
CALCULATION OF DADE DAILY MAXIMUM AND MINIMUM TEMPERATURE
Based on mean daily temperature cycles for the Toronto area and modern "climatological day" practices
CALCULATION OF DADE MEAN MONTHLY TEMPERATURES
Based on average of daily maxima and minima for all complete months
STANDARD DIFFERENCE CALCULATIONS DADE MINUS U.S. STATIONS
For each of the 12 months (Jan. 1831 - Apr. 1841) mean differences in monthly temperatures between Dade (D) and each of 9 U.S. stations (S) (Y = D - S)
STANDARD DIFFERENCE CALCULATIONS TORONTO MINUS U.S. STATIONS
For each of the 12 months (Mar. 1840 - Dec. 1855) mean differences in monthly temperatures between Toronto (T) and each of the same 9 U.S. stations (S) (X = T - S)
FIRST APPROXIMATION OF TORONTO-DADE DIFFERENCES
For each of the 12 months mean differences in monthly temperatures between Toronto and Dade assuming "S" is the same for both periods (Z = x - y = T - D)
CONTINUED NEXT SHEET

FIGURE 6

METHOD "D" - CONTINUED

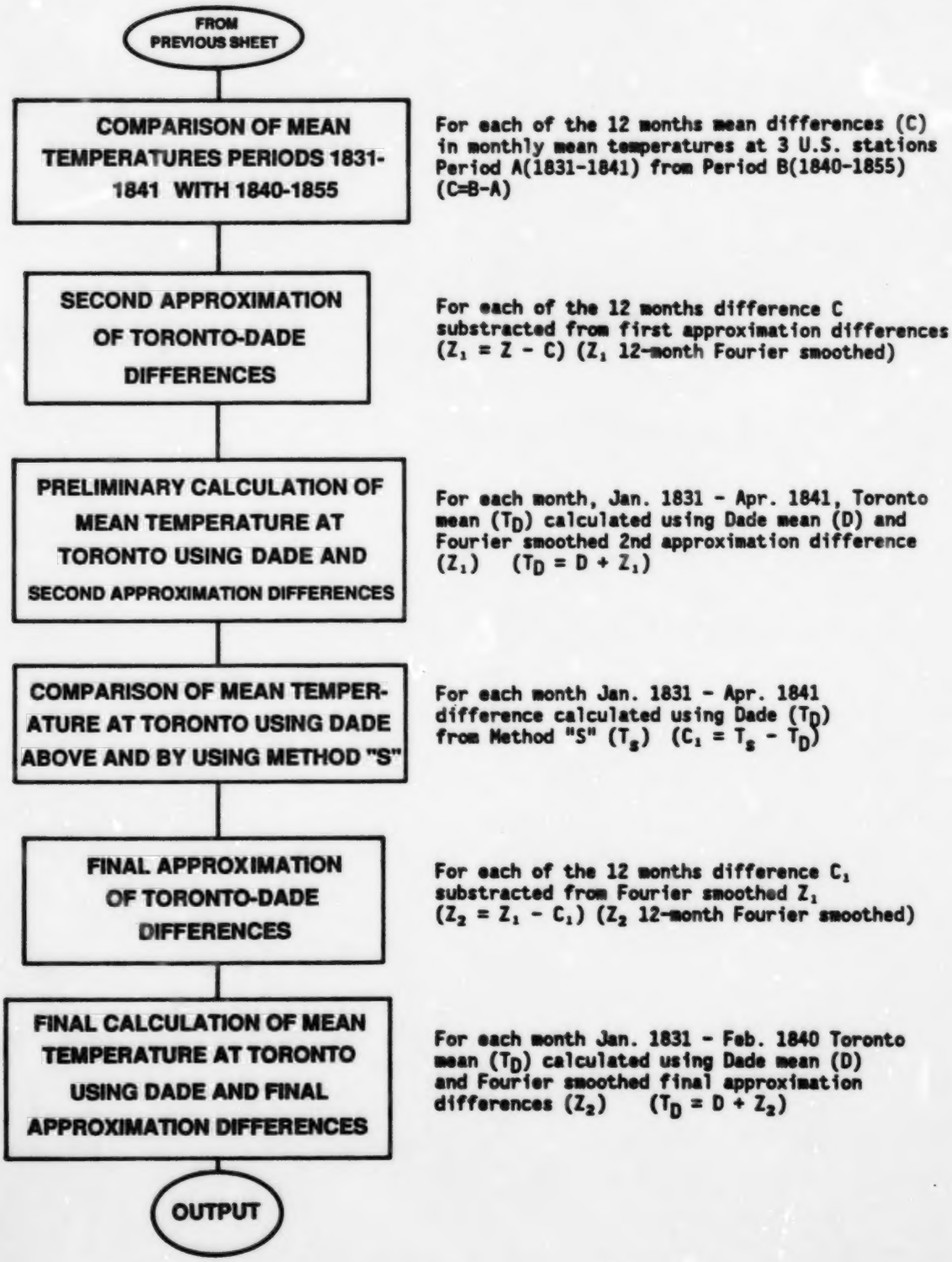
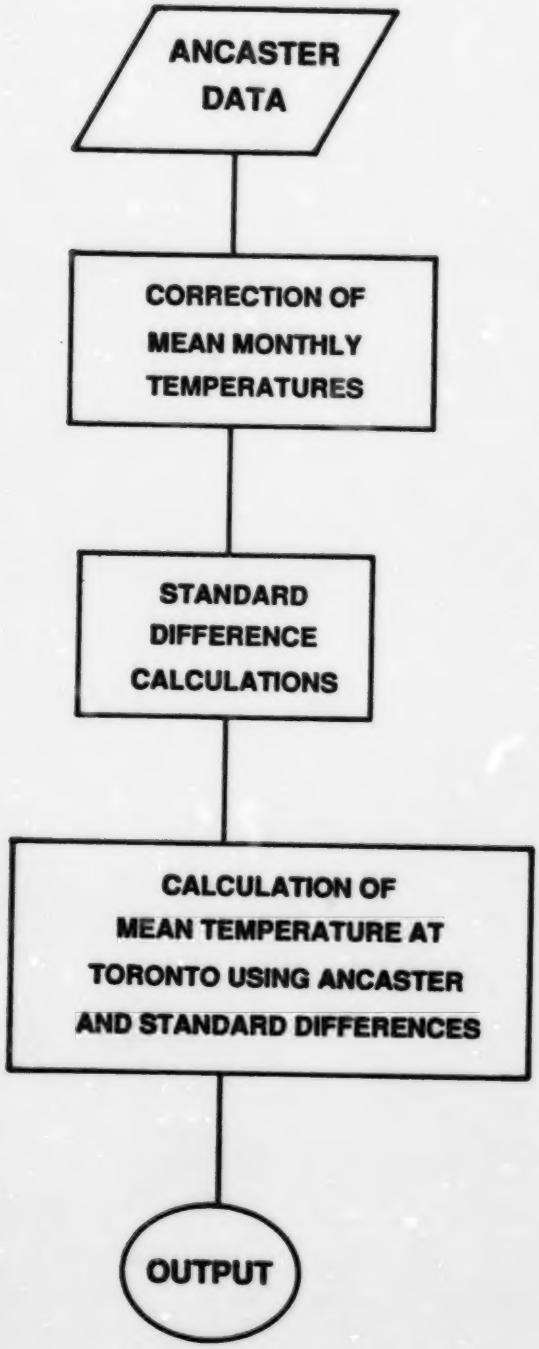

FROM PREVIOUS SHEET
COMPARISON OF MEAN TEMPERATURES PERIODS 1831-1841 WITH 1840-1855
For each of the 12 months mean differences (C) in monthly mean temperatures at 3 U.S. stations Period A(1831-1841) from Period B(1840-1855) (C=B-A)
SECOND APPROXIMATION OF TORONTO-DADE DIFFERENCES
For each of the 12 months difference C substracted from first approximation differences ($Z_1 = Z - C$) (Z_1 12-month Fourier smoothed)
PRELIMINARY CALCULATION OF MEAN TEMPERATURE AT TORONTO USING DADE AND SECOND APPROXIMATION DIFFERENCES
For each month, Jan. 1831 - Apr. 1841, Toronto mean (T_D) calculated using Dade mean (D) and Fourier smoothed 2nd approximation difference (Z_1) ($T_D = D + Z_1$)
COMPARISON OF MEAN TEMPERATURE AT TORONTO USING DADE ABOVE AND BY USING METHOD "S"
For each month Jan. 1831 - Apr. 1841 difference calculated using Dade (T_D) from Method "S" (T_s) ($C_1 = T_s - T_D$)
FINAL APPROXIMATION OF TORONTO-DADE DIFFERENCES
For each of the 12 months difference C_1 substracted from Fourier smoothed Z_1 ($Z_2 = Z_1 - C_1$) (Z_2 12-month Fourier smoothed)
FINAL CALCULATION OF MEAN TEMPERATURE AT TORONTO USING DADE AND FINAL APPROXIMATION DIFFERENCES
For each month Jan. 1831 - Feb. 1840 Toronto mean (T_D) calculated using Dade mean (D) and Fourier smoothed final approximation differences (Z_2) ($T_D = D + Z_2$)
OUTPUT

FIGURE 7

METHOD "A"


ANCASTER DATA
CORRECTION OF MEAN MONTHLY TEMPERATURES
STANDARD DIFFERENCE CALCULATIONS
CALCULATION OF MEAN TEMPERATURE AT TORONTO USING ANCASTER AND STANDARD DIFFERENCES
OUTPUT

Published monthly means Jan. 1835 - Dec. 1845 based on means of two observations per day. 9 a.m. and 9 p.m.

Means based on 9 a.m. and 9 p.m. converted to estimated means based on daily maxima and daily minima using mean daily temperature cycles for the Toronto area

For each of the 12 months, Mar. 1840 Dec. 1845, mean differences in monthly temperatures between Toronto and Ancaster

For each month Jan. 1835 - Feb. 1840

FIGURE 8

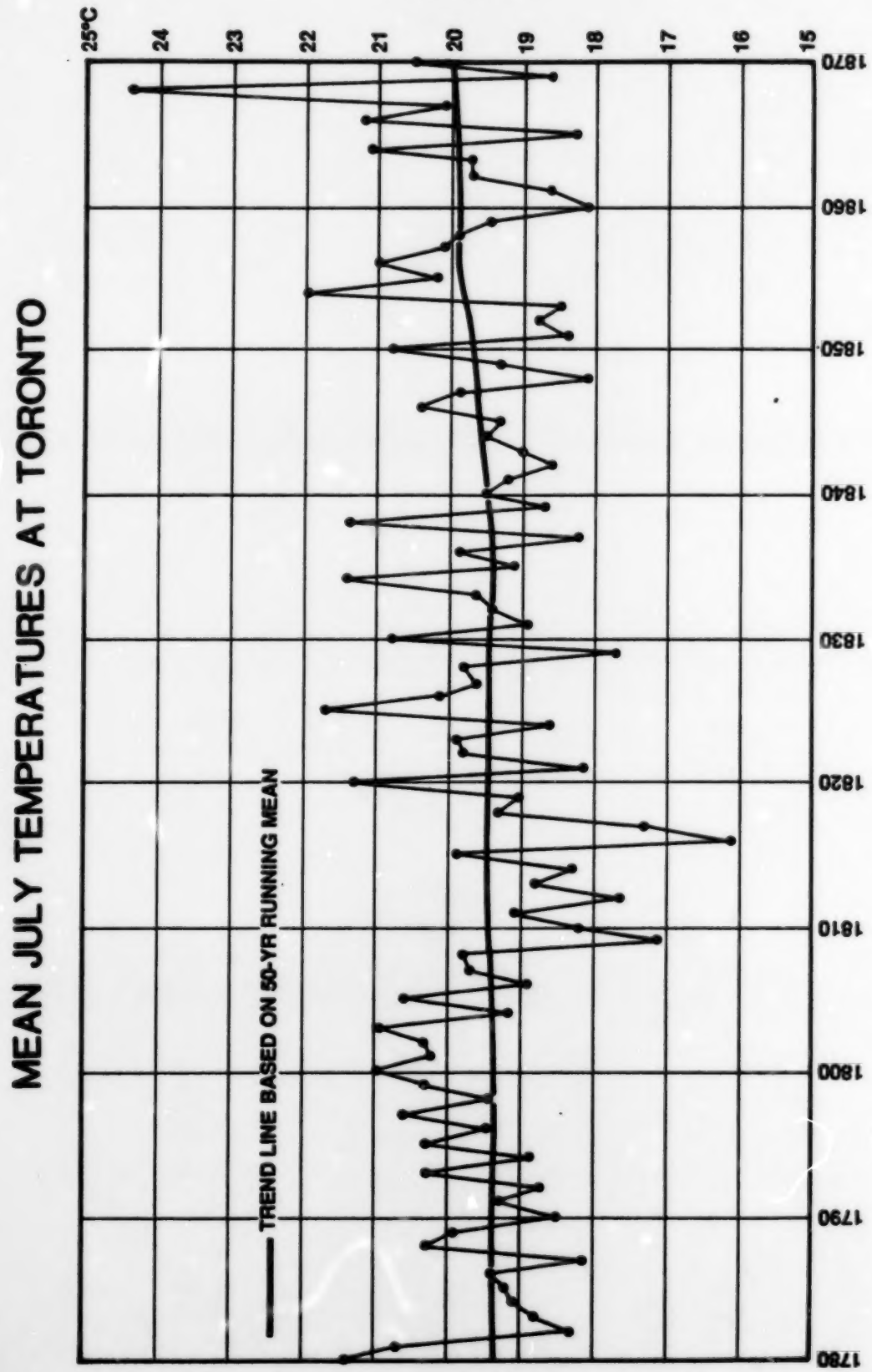
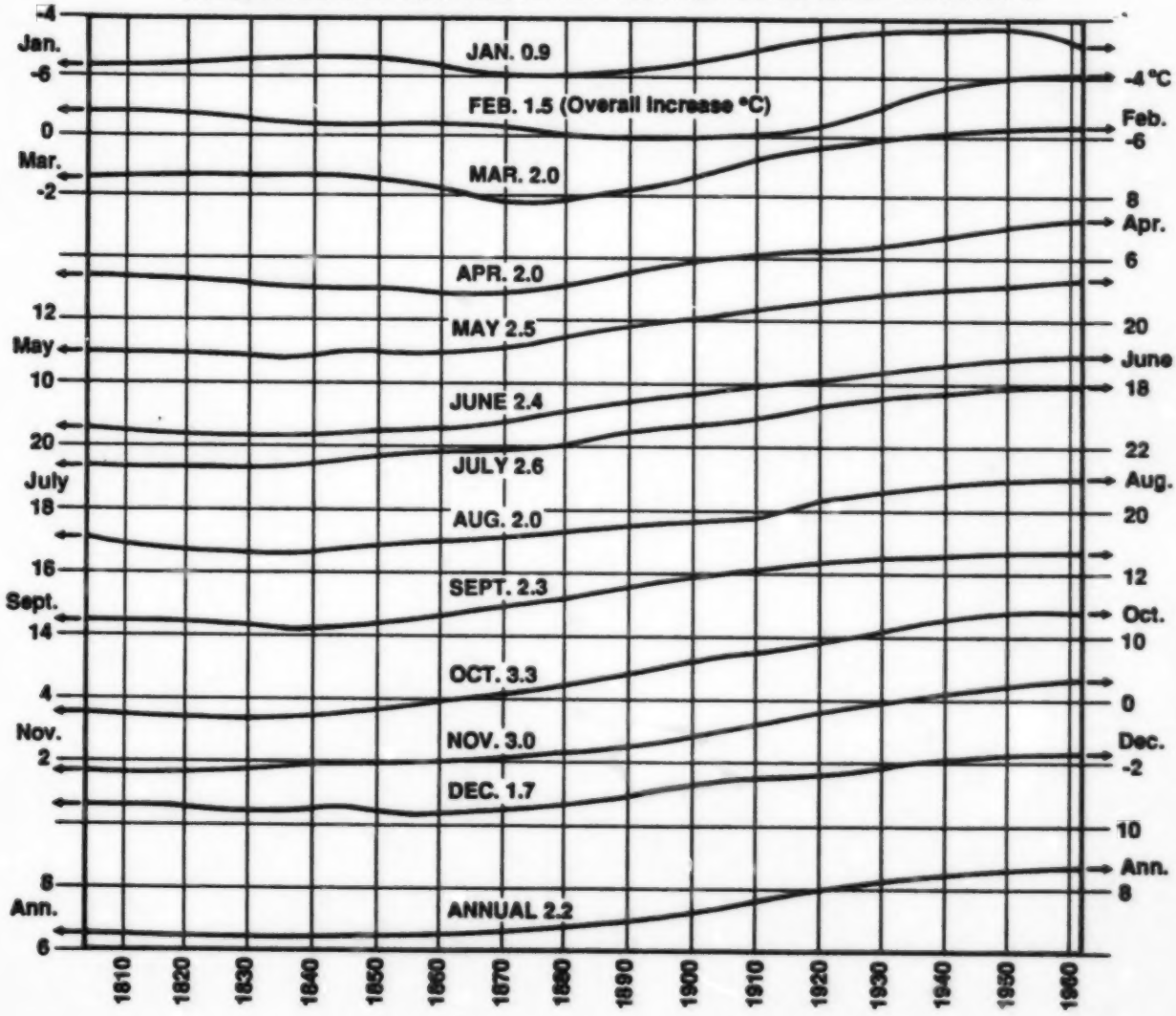

MEAN JULY TEMPERATURES AT TORONTO
25°C
24
23
22
21
20
19
18
17
16
15
1870
1860
1850
1840
1830
1820
1810
1800
1790
1780
TREND LINE BASED ON 50-YR RUNNING MEAN

FIGURE 9

TREND LINES BASED ON 50-YR RUNNING MEANS OF MEAN MONTHLY AND ANNUAL TEMPERATURES AT TORONTO.

(VALUES BEFORE 1804 AND AFTER 1962 ARE CONSIDERED CONSTANT)



TORONTO CITY MEAN TEMPERATURE 1778 - 1988

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANNUAL
1778	M	M	M	M	M	M	20.5	20.9	M	9.3	-.4	-4.8	M
1779	-4.7	M	-.4	7.2	12.8	18.1	M	M	13.9	M	M	M	M
1780	-5.5	-4.9	-2.2	4.1	12.1	16.2	21.4	21.8	13.6	8.8	.6	-2.7	6.9
1781	-1.6	-2.6	-.8	4.7	11.1	15.7	20.7	20.1	14.4	8.6	.2	-3.2	7.3
1782	-6.6	-6.3	-2.7	7.2	12.0	17.7	18.3	20.4	16.0	5.7	.4	-3.4	6.6
1783	-5.9	-3.2	-2.2	5.3	11.5	17.7	18.8	19.2	11.8	5.9	-.6	-4.2	6.2
1784	-8.6	-9.8	-3.1	2.2	10.6	16.6	19.1	20.0	14.3	6.4	3.4	-4.5	5.6
1785	-7.1	-6.1	-4.9	3.9	9.0	17.4	19.2	19.1	13.0	7.6	1.7	-3.3	5.8
1786	-6.8	-4.6	.7	4.6	10.3	17.5	19.4	17.5	14.3	8.9	-.6	-6.2	6.3
1787	-5.0	-5.6	-.4	5.8	9.9	15.6	18.1	18.4	13.2	5.1	3.0	-3.3	6.2
1788	-6.4	-6.5	-1.5	6.3	11.1	16.4	20.3	19.7	15.1	11.2	5.2	-4.3	7.2
1789	-5.0	-8.0	-1.3	5.3	9.3	17.3	19.8	19.9	14.6	5.3	2.7	-1.2	6.6
1790	-2.8	-4.7	-1.6	3.9	11.3	16.7	18.5	19.4	14.7	7.7	1.8	-7.4	6.5
1791	-4.9	-6.5	.7	6.2	12.7	17.2	19.3	19.6	13.8	6.4	1.7	-3.6	6.9
1792	-8.8	-6.2	.3	6.4	12.4	15.6	18.7	18.8	12.3	8.5	2.7	-4.2	6.4
1793	-3.0	-4.4	.7	7.2	12.6	17.3	20.3	20.1	15.2	7.3	1.9	-3.6	7.6
1794	-4.2	-5.5	.9	6.7	12.8	16.2	18.8	19.7	15.9	6.5	2.3	1.6	7.6
1795	-5.4	-5.1	-1.1	6.1	13.2	15.3	20.3	20.9	14.9	8.2	.8	-.4	7.3
1796	-4.5	-5.6	-3.4	6.1	9.8	16.4	19.4	18.4	14.4	6.9	1.3	-7.3	6.0
1797	-6.7	-2.2	-1.0	5.2	9.8	16.0	20.6	19.1	13.9	6.1	-.8	-7.1	6.1
1798	-5.1	-7.1	-1.6	6.1	13.0	17.6	19.4	21.8	15.8	9.0	-.8	-7.6	6.7
1799	-5.6	-7.3	-5.2	3.6	10.6	17.4	20.3	20.2	14.6	7.8	2.0	-3.9	6.2
1800	-5.7	-5.1	-1.4	6.7	11.2	17.8	21.0	19.2	15.1	8.6	.6	-1.8	7.2
1801	-4.4	-4.7	1.2	5.7	12.5	15.9	20.2	18.8	17.0	8.4	2.3	-1.3	7.6
1802	-1.0	-5.3	-.3	5.9	10.7	17.2	20.3	20.7	16.4	10.0	2.7	-3.3	7.8
1803	-4.7	-3.1	-1.4	6.4	9.3	17.3	20.9	20.2	14.8	9.7	.9	-.3	7.5
1804	-6.7	-4.5	-1.7	5.7	12.7	17.9	19.1	19.4	16.3	7.8	3.0	-4.9	7.0
1805	-7.5	-3.9	1.3	7.7	11.8	16.9	20.6	21.3	16.7	6.2	2.7	1.3	7.9
1806	-5.0	-1.2	-3.3	3.4	11.9	17.6	18.9	18.1	15.1	7.7	2.5	-3.6	6.0
1807	-6.2	-5.3	-2.9	4.7	10.1	15.2	19.7	19.1	13.1	8.2	.3	-.3	6.3
1808	-5.7	-3.1	.6	5.8	10.0	17.1	19.8	17.7	14.4	7.2	2.6	-1.9	7.0
1809	-6.9	-6.9	-2.3	5.1	10.4	15.6	17.1	18.1	12.9	11.2	-.3	-.9	6.1
1810	-5.0	-3.3	-1.8	5.2	12.2	17.1	18.2	18.1	14.8	6.3	.9	-3.7	6.6
1811	-5.3	-5.9	.8	5.2	10.5	16.8	19.1	18.5	14.3	10.0	2.2	-3.9	6.9
1812	-6.9	-5.9	-4.0	4.3	7.4	15.4	17.6	17.7	12.3	7.1	1.2	-3.7	5.2
1813	-6.7	-5.7	-3.2	5.9	9.6	16.6	18.8	20.1	16.0	6.8	2.2	-4.1	6.4
1814	-6.4	-3.8	-2.4	6.2	13.1	15.9	18.3	18.8	14.3	7.0	1.7	-5.0	6.5
1815	-6.6	-7.1	-1.0	5.1	8.9	15.4	19.9	17.8	13.1	6.6	2.3	-4.8	5.8
1816	-7.6	-5.1	-3.4	3.1	8.5	13.3	16.1	17.9	12.1	7.8	3.4	-3.7	5.2
1817	-6.4	-9.9	-3.4	4.3	8.4	13.9	17.3	18.2	14.8	5.6	2.4	-3.7	5.1
1818	-6.3	-9.4	-2.4	2.4	9.2	16.9	19.3	17.4	12.9	6.7	3.2	-6.5	5.3
1819	-3.4	-3.4	-4.8	4.1	9.4	16.4	19.0	18.7	16.4	6.8	2.9	-3.8	6.5
1820	-7.2	-3.2	-2.4	6.0	10.2	17.2	21.3	18.7	15.9	6.8	-.4	-5.7	6.4
1821	-9.3	-2.9	-2.5	2.8	10.9	17.1	18.1	19.9	15.4	7.2	1.7	-4.5	6.2
1822	-7.7	-5.4	.7	5.7	12.7	16.8	19.8	19.2	16.5	8.4	4.1	-3.3	7.3
1823	-4.9	-8.3	-2.4	5.9	10.5	16.4	19.9	19.3	13.3	6.2	-.8	-2.6	6.0
1824	-2.7	-4.4	-1.7	5.5	9.4	15.3	18.6	17.6	14.1	7.7	1.4	-.9	6.7
1825	-4.1	-3.8	1.6	6.5	11.4	18.2	21.7	19.4	13.8	9.2	1.6	-3.7	7.7
1826	-4.4	-3.0	-.6	3.2	15.2	17.3	20.1	19.9	16.0	8.8	2.2	-3.2	7.6
1827	-7.9	-3.8	-.2	7.4	10.8	15.9	19.6	18.5	14.8	8.4	-.8	-2.3	6.7
1828	-2.4	.7	.7	4.1	12.2	19.8	19.8	20.4	15.2	7.2	3.0	.0	8.4
1829	-6.1	-8.2	-2.6	5.6	13.4	16.1	17.7	18.5	12.1	7.7	1.5	.8	6.4
1830	-6.4	-5.8	.2	9.1	10.7	15.1	20.8	18.6	13.5	8.9	6.1	-1.3	7.5
1831	-6.9	-8.6	2.4	5.7	10.8	18.9	18.9	19.8	14.6	8.2	1.8	-10.1	6.3
1832	-5.8	-6.9	-.7	4.0	9.2	17.1	19.4	17.9	14.3	8.7	1.9	-1.5	6.5

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANNUAL
1833	-2.9	-7.3	-1.8	7.7	13.3	15.2	19.6	17.9	14.8	7.2	.2	-1.7	6.9
1834	-7.5	-1.7	-.2	7.0	11.2	15.9	21.4	19.2	14.0	6.1	1.3	-4.5	6.9
1835	-4.8	-8.4	-1.1	4.6	12.4	16.4	19.1	17.4	11.6	9.1	1.6	-5.6	6.0
1836	-4.9	-9.4	-4.2	3.6	11.0	15.1	19.9	16.8	14.2	3.9	.3	-4.6	5.1
1837	-7.8	-5.8	-3.4	3.4	8.6	16.1	18.2	16.7	13.5	6.0	2.4	-3.3	5.4
1838	-2.8	-10.3	1.8	1.8	8.4	18.2	21.4	19.1	14.9	6.4	-.9	-6.4	6.0
1839	-4.8	-3.6	-.9	8.2	10.9	14.2	18.7	17.0	12.3	9.8	1.2	-2.3	6.7
1840	-7.8	-1.9	1.2	6.7	12.4	15.7	19.5	19.0	12.6	7.4	2.1	-4.9	6.8
1841	-4.5	-5.5	-2.3	4.3	10.9	19.4	19.2	18.7	16.1	5.7	1.3	-2.0	6.8
1842	-2.9	-2.2	2.7	7.0	10.2	14.5	18.6	19.5	13.8	7.8	1.1	-3.8	7.2
1843	-2.1	-8.5	-5.8	5.1	10.8	14.8	19.0	19.4	16.4	6.4	.7	-.7	6.3
1844	-6.5	-3.6	.2	9.3	13.2	16.1	19.5	18.4	15.3	6.6	1.9	-2.1	7.4
1845	-3.2	-3.5	1.6	5.8	10.3	15.9	19.3	19.4	12.8	7.5	2.6	-6.3	6.9
1846	-3.8	-7.5	-.3	6.5	13.1	17.3	20.4	19.9	17.3	7.2	5.1	-2.8	7.7
1847	-5.3	-5.6	-3.3	3.3	11.5	14.4	19.9	17.8	13.0	6.8	3.5	-2.0	6.2
1848	-2.7	-3.0	-2.2	4.9	12.1	16.4	18.0	19.6	12.2	7.6	.9	-1.5	6.9
1849	-7.3	-7.6	.4	3.3	8.9	16.7	19.3	18.2	14.2	7.7	5.6	-3.6	6.3
1850	-1.9	-4.0	-1.7	3.3	9.8	17.4	20.8	19.0	12.8	6.5	2.9	-5.6	6.6
1851	-4.5	-2.6	.4	5.0	10.7	15.0	18.4	17.3	14.9	8.7	-.1	-6.3	6.4
1852	-8.1	-5.2	-3.5	3.0	10.6	15.8	18.8	18.2	13.4	8.8	1.6	-.2	6.1
1853	-5.6	-5.3	-1.5	5.0	9.8	17.9	18.5	20.0	14.9	6.2	3.1	-4.3	6.6
1854	-5.9	-7.0	-1.3	4.1	10.0	16.8	22.0	20.1	16.1	10.1	1.8	-5.6	6.8
1855	-3.9	-10.1	-2.2	5.9	11.9	15.5	20.2	18.0	15.2	6.5	2.9	-3.4	6.4
1856	-9.8	-10.2	-5.7	5.6	10.1	16.7	21.0	17.5	13.5	7.0	2.2	-5.5	5.2
1857	-12.1	-2.2	-3.0	1.9	9.4	14.1	20.1	18.2	14.4	7.1	.7	-1.1	5.6
1858	-1.4	-8.1	-1.4	5.2	9.3	18.5	19.9	19.6	15.2	9.9	1.2	-2.6	7.1
1859	-4.1	-3.5	2.4	4.4	12.9	14.7	19.4	19.6	13.4	6.6	3.6	-7.2	6.9
1860	-4.6	-5.3	1.5	4.3	13.3	17.8	18.1	18.4	12.9	8.7	3.6	-4.5	7.0
1861	-6.9	-3.7	-2.8	5.9	8.9	16.1	18.6	19.0	15.1	9.2	2.9	-.8	6.8
1862	-5.9	-5.7	-1.7	4.4	11.0	15.6	19.7	19.6	15.8	9.0	2.0	-1.7	6.8
1863	-2.1	-5.2	-3.3	5.4	12.7	16.0	19.7	19.4	13.3	8.2	4.0	-2.6	7.1
1864	-4.8	-3.8	-1.7	5.1	12.5	17.2	21.1	20.8	13.6	7.7	2.9	-3.3	7.3
1865	-8.1	-5.5	.2	6.0	11.4	18.6	18.3	18.5	18.7	7.4	3.9	-1.7	7.3
1866	-7.0	-5.5	-2.6	6.9	9.3	15.9	21.2	16.2	13.6	10.4	3.7	-3.6	6.5
1867	-8.1	-2.2	-2.5	4.9	8.5	18.1	20.1	20.5	15.1	10.4	3.9	-5.3	7.0
1868	-7.8	-8.1	-.3	3.4	11.2	16.4	24.4	19.8	14.1	6.2	2.6	-4.9	6.4
1869	-2.1	-4.5	-4.7	4.6	10.4	14.8	18.6	17.7	16.5	6.1	.3	-1.6	6.3
1870	-4.0	-5.9	-2.9	7.3	13.9	19.4	20.5	19.5	16.5	10.5	2.9	-3.2	7.9
1871	-6.2	-4.8	1.6	6.8	12.0	16.6	19.0	19.9	13.2	9.7	-.4	-5.4	6.8
1872	-6.2	-6.2	-6.1	4.8	11.0	17.1	21.2	21.0	15.4	7.6	.8	-8.2	6.0
1873	-8.3	-7.5	-3.3	4.2	11.0	17.3	20.0	19.1	13.7	7.6	-2.4	-2.0	5.8
1874	-4.4	-5.6	-1.4	.8	11.5	17.1	19.5	19.3	17.4	8.5	1.7	-3.9	6.7
1875	-9.2	-12.6	-4.9	2.5	10.9	16.1	19.2	18.7	13.3	6.4	-.1	-3.0	4.8
1876	-1.3	-5.0	-3.3	3.6	10.7	18.6	20.3	21.2	14.3	5.8	2.9	-8.3	6.6
1877	-8.8	-2.0	-3.6	6.5	12.0	16.7	21.2	20.9	16.6	9.9	3.0	1.2	7.8
1878	-4.5	-3.0	3.1	9.6	11.5	17.0	22.4	20.5	16.4	9.6	2.5	-4.2	8.4
1879	-7.0	-8.1	-1.8	4.2	12.0	16.6	20.5	18.5	13.2	12.7	2.0	-3.2	6.6
1880	.4	-2.6	-1.7	5.3	14.7	18.7	19.7	19.3	15.8	7.3	-1.2	-6.1	7.5
1881	-9.0	-7.1	-1.1	4.3	14.5	15.9	21.5	21.2	20.2	9.8	2.8	1.0	7.8
1882	-5.1	-1.0	-.2	4.6	9.5	16.3	19.4	19.8	16.4	10.9	2.0	-3.7	7.4
1883	-8.2	-7.1	-5.9	3.5	9.6	16.7	18.5	17.6	12.5	7.2	2.8	-3.5	5.3
1884	-9.2	-4.9	-2.3	5.0	10.6	18.2	17.8	18.6	16.5	9.1	1.1	-3.8	6.4
1885	-8.3	-11.9	-8.2	2.9	11.0	15.6	19.9	17.3	13.8	7.6	3.5	-2.6	5.1
1886	-7.4	-7.7	-1.2	7.2	11.7	16.2	19.0	18.7	14.9	9.1	1.9	-6.2	6.4
1887	-8.0	-6.0	-4.1	4.2	14.7	17.5	22.9	19.0	13.7	6.5	1.6	-2.3	6.6

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANNUAL
1888	-9.6	-6.0	-5.4	4.0	10.6	18.1	19.0	19.1	13.7	6.3	3.1	-1.5	6.0
1889	-2.5	-8.3	.5	6.3	12.2	15.7	20.6	18.7	15.6	6.0	3.7	1.2	7.5
1890	-1.4	-2.4	-2.4	5.7	10.1	18.7	19.8	18.1	14.2	9.2	2.8	-5.3	7.3
1891	-4.9	-2.4	-1.9	6.3	10.8	18.0	17.9	18.9	17.3	8.7	2.6	.8	7.7
1892	-7.0	-4.4	-2.3	5.3	10.9	18.6	20.1	19.8	15.6	8.7	1.7	-3.6	7.0
1893	-10.0	-7.6	-1.7	4.4	11.1	19.3	20.2	19.3	14.1	9.2	2.9	-4.7	6.4
1894	-2.1	-6.5	2.1	7.0	11.3	19.3	20.6	18.6	17.1	10.2	1.2	-.4	8.2
1895	-6.1	-8.7	-4.4	6.3	13.1	19.9	19.1	18.8	16.0	6.1	2.8	-1.4	6.8
1896	-5.8	-5.6	-4.8	8.0	15.7	18.1	20.7	19.8	14.1	7.2	4.3	-2.4	7.4
1897	-5.1	-4.1	-.1	6.3	11.6	16.4	22.5	18.6	16.3	10.5	3.7	-2.2	7.9
1898	-3.8	-4.2	2.8	6.5	13.2	18.8	21.7	21.4	17.8	10.3	2.0	-3.1	8.6
1899	-5.0	-7.1	-2.1	7.2	13.0	18.6	20.5	21.1	14.0	10.4	4.7	-1.8	7.8
1900	-3.4	-6.7	-4.8	7.5	12.9	18.4	20.6	22.5	18.0	13.5	3.7	-1.7	8.4
1901	-4.7	-8.5	-1.2	8.0	12.5	18.5	22.9	20.7	16.6	9.4	1.4	-3.0	7.7
1902	-4.8	-6.0	3.1	6.7	11.9	15.6	20.5	18.6	15.8	9.3	6.1	-4.3	7.7
1903	-5.0	-3.5	4.3	6.6	13.3	16.6	20.7	17.7	16.2	10.5	1.7	-5.1	7.8
1904	-8.9	-10.4	-1.9	4.0	13.2	17.3	19.7	18.2	14.8	7.8	2.2	-5.4	5.9
1905	-7.8	-8.6	-.8	5.7	11.5	17.6	21.0	19.7	16.8	9.3	2.7	-.5	7.2
1906	-.6	-5.4	-2.8	7.1	12.4	18.7	21.2	22.1	18.3	9.6	3.0	-4.9	8.2
1907	-5.5	-7.5	1.0	3.6	9.0	17.7	20.7	18.6	16.5	7.2	2.8	-1.4	6.9
1908	-4.2	-7.1	-.3	5.5	13.5	19.0	21.6	19.5	17.7	10.8	4.3	-1.6	8.2
1909	-3.1	-3.0	-1.1	5.0	12.1	18.6	19.9	20.7	15.7	7.9	4.8	-3.3	7.9
1910	-3.6	-6.1	3.8	8.3	11.5	18.2	21.8	19.8	15.6	10.7	2.3	-6.0	8.0
1911	-3.4	-3.7	-1.1	6.3	16.3	18.6	22.0	20.8	15.9	9.7	2.2	1.1	8.7
1912	-10.0	-7.3	-3.5	5.5	12.9	16.8	21.0	17.8	17.1	10.4	4.7	.4	7.2
1913	-.4	-6.5	.8	8.0	12.4	18.2	21.3	20.4	15.3	11.0	5.7	.8	8.9
1914	-3.6	-9.2	-.7	5.3	14.8	18.0	21.4	20.1	16.2	11.6	3.4	-3.5	7.8
1915	-4.6	-3.3	-1.2	10.0	11.2	16.9	20.3	19.1	17.5	11.1	4.8	-2.5	8.3
1916	-1.0	-7.3	-3.7	7.0	12.4	15.7	24.5	22.3	16.2	9.8	3.2	-2.8	8.0
1917	-5.2	-8.3	.1	5.1	9.7	16.0	21.4	19.9	14.8	7.0	1.4	-7.0	6.2
1918	-10.4	-6.0	.9	6.5	14.0	16.4	21.0	21.7	13.6	10.8	5.6	-.4	7.8
1919	-1.6	-2.1	1.0	5.9	13.0	22.5	23.0	20.0	17.5	11.7	3.5	-5.2	9.1
1920	-10.6	-6.6	1.1	4.6	12.5	18.8	19.2	21.1	17.7	12.8	2.7	-.3	7.8
1921	-2.3	-2.0	3.7	9.6	14.6	20.4	25.5	20.1	19.9	10.2	2.4	-2.0	10.0
1922	-4.8	-3.1	1.3	7.5	15.4	19.3	20.9	20.6	17.6	9.9	4.9	-2.0	9.0
1923	-5.7	-7.4	-2.7	5.8	10.9	19.2	20.6	18.8	16.0	9.4	3.9	2.4	7.6
1924	-4.8	-6.5	-.2	6.0	10.0	17.2	19.6	19.4	13.9	10.4	3.9	-4.5	7.0
1925	-6.5	-2.6	1.7	7.4	10.5	19.3	19.8	20.5	16.5	5.8	3.2	-3.1	7.7
1926	-4.1	-6.1	-3.3	3.0	11.6	15.4	19.9	20.3	15.1	8.4	3.1	-4.5	6.6
1927	-6.0	-2.8	1.8	6.4	11.6	16.5	20.5	18.2	17.4	11.7	5.0	-1.6	8.2
1928	-3.8	-4.3	-.8	5.4	12.3	16.4	21.1	21.5	14.3	10.5	4.3	.5	8.1
1929	-5.0	-5.6	2.7	7.6	11.7	17.7	20.4	18.6	16.8	9.2	3.3	-3.7	7.8
1930	-5.1	-2.9	-.6	6.1	14.2	19.4	21.2	20.7	17.3	9.5	4.9	-1.8	8.6
1931	-4.0	-3.0	.8	7.1	13.3	18.9	23.1	20.8	18.9	11.8	7.7	.8	9.7
1932	1.9	-1.3	-1.6	5.0	13.0	19.2	19.9	21.0	16.7	10.8	2.1	-.9	8.8
1933	.9	-3.3	-.2	7.3	14.2	19.8	22.8	20.7	17.1	8.9	-.2	-4.3	8.6
1934	-3.4	-12.1	-2.2	5.6	14.3	19.9	22.0	18.7	17.2	9.3	5.7	-3.6	7.6
1935	-6.3	-5.4	2.0	6.5	11.1	17.7	23.3	21.1	14.9	10.1	4.4	-5.2	7.9
1936	-5.3	-8.1	1.4	4.3	14.9	18.3	22.9	20.6	17.1	9.5	1.3	-.3	8.1
1937	-.5	-2.3	-1.9	6.3	13.7	18.9	21.9	22.6	15.7	8.7	3.7	-2.6	8.7
1938	-5.4	-2.7	2.1	8.0	12.9	18.8	22.2	22.8	15.0	11.2	5.1	-.6	9.1
1939	-4.6	-4.0	-1.8	4.8	14.4	18.7	22.2	22.4	16.5	10.1	2.8	-.4	8.4
1940	-7.5	-4.2	-3.2	5.2	12.3	17.4	21.6	20.5	16.3	8.9	3.4	-1.2	7.5
1941	-5.3	-4.5	-2.7	10.4	14.8	20.5	22.3	20.1	17.5	11.1	5.7	.2	9.2

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANNUAL
1942	-4.0	-6.2	2.4	9.9	13.7	19.0	21.3	20.8	16.4	10.8	4.4	-4.0	8.7
1943	-6.9	-3.5	-1.1	4.0	12.8	20.8	21.9	20.5	15.6	9.4	3.3	-2.9	7.8
1944	-1.1	-3.7	-1.9	4.8	15.6	19.1	22.0	22.3	16.8	10.3	4.5	-3.5	8.8
1945	-9.4	-3.4	6.2	8.7	10.3	17.4	20.6	21.0	16.8	9.2	4.4	-4.2	8.1
1946	-3.4	-5.2	6.1	7.1	12.5	18.2	21.4	19.1	17.2	12.3	5.9	-1.5	9.1
1947	-2.9	-5.3	-.6	5.8	11.3	18.1	21.0	23.0	17.5	14.5	3.8	-2.7	8.6
1948	-7.3	-5.0	.1	8.5	11.9	18.8	22.0	21.7	19.0	9.4	7.5	-.4	8.9
1949	-1.6	-1.4	.4	7.7	14.7	22.2	23.3	22.9	15.1	13.1	3.0	.2	10.0
1950	-.1	-4.6	-2.2	4.6	13.2	18.3	20.8	20.4	15.5	12.2	3.7	-1.9	8.3
1951	-2.6	-2.5	1.7	7.6	14.8	18.7	21.9	20.6	16.7	11.4	1.7	-1.7	9.0
1952	-2.6	-1.8	.1	9.8	12.7	19.7	23.5	20.8	18.0	8.5	5.7	1.0	9.6
1953	-1.3	-.8	2.5	7.1	13.8	19.5	22.3	22.0	17.4	12.0	6.8	1.1	10.2
1954	-6.0	.5	.0	7.9	12.5	19.9	21.5	20.1	16.5	12.0	5.3	-1.8	9.0
1955	-3.9	-3.1	.2	10.5	15.5	20.2	24.6	23.5	16.8	12.2	3.7	-3.8	9.7
1956	-3.9	-2.2	-.9	5.5	11.2	19.2	20.5	20.2	14.4	12.2	5.2	.1	8.5
1957	-6.5	-1.4	2.2	8.6	12.6	20.0	21.5	20.2	16.8	10.4	5.6	1.1	9.3
1958	-3.8	-6.2	2.6	9.1	12.7	16.4	21.6	20.8	17.1	10.8	5.4	-5.2	8.4
1959	-5.8	-5.7	-.6	8.0	14.5	20.3	22.9	24.2	19.3	10.4	3.0	-.2	9.2
1960	-3.5	-2.9	-3.7	8.1	13.9	18.6	20.9	21.1	18.6	11.0	6.5	-3.9	8.7
1961	-6.4	-1.2	1.1	5.4	12.4	18.1	21.8	21.4	20.3	13.0	4.8	-1.2	9.1
1962	-5.5	-6.2	1.4	7.9	16.4	19.6	20.6	21.3	15.6	11.4	4.1	-2.7	8.7
1963	-6.9	-7.5	2.0	7.9	12.6	19.8	22.3	19.7	15.0	14.6	7.3	-5.3	8.5
1964	-1.8	-3.2	.7	7.0	15.6	18.7	23.0	18.6	16.3	10.0	5.8	-1.1	9.1
1965	-5.1	-4.2	-.8	5.4	15.3	18.5	19.6	19.9	16.9	9.3	4.5	1.2	8.4
1966	-5.9	-3.0	2.1	6.4	11.0	20.1	23.2	21.0	15.9	9.9	5.6	-1.6	8.7
1967	-1.1	-6.7	-.6	7.3	10.2	20.9	20.9	19.9	16.1	10.5	2.6	-.1	8.3
1968	-6.2	-5.9	2.1	9.3	11.5	18.0	21.5	20.9	18.6	12.2	4.3	-3.0	8.6
1969	-4.1	-2.6	-.2	8.4	13.1	17.5	22.2	23.0	17.8	10.6	4.9	-3.4	8.9
1970	-7.4	-4.5	-.3	8.4	13.6	19.6	22.5	22.2	17.6	12.3	6.3	-2.9	9.0
1971	-6.8	-2.8	-.7	6.2	13.5	19.7	21.4	20.8	19.2	14.5	4.4	.9	9.2
1972	-3.6	-4.9	-1.8	5.3	15.4	17.5	22.3	20.6	17.9	8.8	3.4	-.7	8.4
1973	-2.2	-4.9	4.9	7.8	12.1	20.0	22.9	23.7	18.0	12.7	5.6	-1.9	9.9
1974	-3.0	-5.3	.5	8.7	11.8	18.2	22.4	22.1	15.8	9.1	5.0	1.3	8.9
1975	-1.0	-1.8	-.6	4.4	17.0	20.1	23.3	21.8	15.4	12.0	8.5	-2.3	9.7
1976	-6.4	-.1	2.1	9.3	12.4	20.9	20.6	20.6	16.5	8.4	2.2	-5.0	8.5
1977	-9.1	-3.8	4.1	8.9	16.5	18.6	22.3	20.4	17.2	10.3	5.9	-2.0	9.1
1978	-6.7	-6.8	-1.3	5.9	14.4	18.5	21.5	21.1	16.5	10.1	4.6	-.9	8.1
1979	-6.0	-8.8	2.9	6.6	12.7	18.3	21.9	19.9	16.7	9.5	5.4	.3	8.3
1980	-3.6	-5.7	-.1	7.8	15.5	16.1	21.9	22.5	16.9	8.6	3.5	-4.3	8.3
1981	-7.9	-.4	1.9	8.3	13.4	18.9	22.2	20.8	16.1	8.3	5.1	-1.1	8.8
1982	-7.8	-4.7	.2	5.9	15.2	16.6	22.2	18.8	16.1	11.3	5.6	2.3	8.5
1983	-2.3	-1.5	2.2	6.9	11.3	20.0	23.4	22.4	18.2	10.9	4.5	-4.2	9.3
1984	-6.6	.5	-2.6	8.2	11.7	19.7	21.2	22.3	15.6	12.0	4.8	1.7	9.0
1985	-6.2	-3.4	2.1	8.6	14.7	17.1	21.0	20.5	18.4	11.4	4.8	-3.2	8.8
1986	-3.9	-4.4	2.2	9.3	15.7	17.9	22.0	20.0	16.0	10.6	3.5	.4	9.1
1987	-2.5	-3.2	3.6	10.3	15.8	20.8	23.7	21.1	17.0	8.8	4.9	1.2	10.1
1988	-3.1	-4.1	.9	7.3	15.3	19.7	24.2	22.7	16.6	8.7	6.0	-1.0	9.4